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ABSTRACT

Impediments that hamper learning statistics, the relative characteristics of successful and unsuccessful learners, and the nature of interventions required to make learning statistics successful and meaningful were studied. Twenty graduate and 15 undergraduate students in different fields from a large public university, a small private college, and the engineering department of a large polytechnic institute, all in the capital district region of New York participated. The study was conducted using methods for constructing a grounded theory, with continual checking back with subjects to see if they considered emerging data categories credible. Initial interviews with the 35 subjects were conducted using topics, derived from a literature review, to stimulate student recollection of the learning experience. All the students except for one experienced a traditional algorithmic approach to instruction through lecture and practice problems. Rechecking student opinions resulted in a preliminary theory of learning statistics that identifies teaching ability as an integrating category. Many students explicitly identified teaching ability, or the lack thereof, as the single most important contributor to their success or failure. A compilation of student opinions provides teaching-ability components, focusing on an interest in students and the subject. An appendix presents participant profiles. (Contains 1 table and 17 references.) (SLD)

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COLLEGE STUDENTS' THEORY OF LEARNING INTRODUCTORY STATISTICS PHASE ONE

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INTRODUCTION

In today's information age there is a growing need for statistical literacy and ability to apply basic statistical methods to real world problems in the work place. For the average citizen, it is almost impossible to read the daily paper without encountering at least one report that presents an analysis of data. In business, industry, and even government there is increasing use of Total Quality Management (TQM) with its emphasis on use of analytical studies as a management tool. No longer is statistics the exclusive domain of mathematicians and researchers.

Examination of the course schedule of any large college or university provides evidence of an increasing interest in statistics education. In any given semester there may be well over 30 sections of introductory statistics across many departments. Given the general need for statistical literacy, steps to ensure that all college students receive a basic statistical education regardless of their particular career goals are clearly being taken.

These educational measures seem encouraging until the experience of learning statistics is closely examined. Many students classify that experience as one of the most difficult, unsuccessful and stress evoking of their entire academic careers. Some who are otherwise confident and successful have described

themselves as "retarded" with respect to learning statistics. It's negative reputation is so great that students with a statistics requirement tend to take it early to "get it over with" or engage in avoidance behavior until they run out of alternatives. Also, with the exception of those pursuing careers as statisticians or researchers, few report gaining knowledge of any useful value in their personal or professional lives.

This study is undertaken with the belief that offering or requiring wider variety of statistics courses will do little to meet society's needs until we learn how to teach statistics in a way that effectively meets the learner's needs. The overall purpose of the study is to determine the impediments that exist for learners, the relative characteristics of successful and unsuccessful learners, and the nature of interventions required to make learning statistics a successful, meaningful, and useful experience for all learners. The targeted group of learners are both undergraduate and graduate students in any major.

METHOD

Grounded Theory Approach

The study is being conducted using methods for constructing a grounded theory as summarized by Strauss and Corbin (1990). The approach is essentially one of inductively developing a theory of the reality of learning introductory statistics from data provided by those actually engaged in the process. Procedures include data

collection interviews; coding (labeling), categorizing, and dimensionalizing data; and hypothesizing and validating causal and conditional relationships. Throughout the process there is continual member checking (i.e., checking back with subjects to determine whether they find the emerging data categories to be credible).

Use of the Literature

One of the major differences between this qualitative approach and quantitative methods is the manner in which variables and their relationships are determined. This difference entails very different uses of relevant literature. In quantitative research, variables are defined, relationships hypothesized, and methods of analysis specified in advance of data collection, which is constrained by the pre-determined research design. The theoretical and experimental literature serves as a primary source for this process. Qualitative research, in contrast, begins with subject generated information which is then analyzed to determine relevant variables and their relationships. The subject generated data is the primary data and discovery the primary process in qualitative analysis. The literature plays an important but secondary role in several ways.

The literature can be used to stimulate theoretical sensitivity, which is the researcher's awareness of the subtleties of meaning in the data. It may also be a source of secondary data. In addition, the literature can stimulate questions, direct

theoretical exploration and be used for supplementary validation. In this study, it is proposed to use the literature in all of these ways. Therefore, an extensive literature review was undertaken prior to any data collection. This review was limited, however, to readings which pertain specifically to teaching or learning statistics at the post secondary level.

It was discovered that two groups of professionals are working on statistics education issues at what appears to be at least a moderate degree of distance from each other. One of these groups is composed primarily of mathematical statisticians whose areas of application tend to be the natural sciences, industry, and business. Their educational concerns focus largely on curriculum, teacher qualification, and student preparation. Their publications most frequently appear under the auspices of the American Statistical Association (ASA) or in journals specifically aimed at the higher education community.

The second group is comprised mainly of those whose who work in the behavioral sciences (psychology, sociology and education). Much of their writing appears in publications of the American Psychological Association (APA) and in journals that address educational matters at all levels. The literature of this group focuses on issues such as anxiety, gender differences, and cognitive maturity. Both groups deal with instructional interventions and the use of computers.

When relevant, secondary and/or validating data from the literature will be incorporated into the category descriptions.

Absence of such secondary data in any category or sub-category indicates that none of relevance was found in the preliminary literature review. As part of the selective coding to be done in phase two, focused literature reviews will be undertaken.

Procedures

Phase one of the study included the following specific activities:

1. Initial interviews with current or recent students of introductory statistics for initial data collection.
2. Collection of secondary and/or validating data from the literature.
3. Open and axial coding of data, i.e., analysis of initial data by coding (labeling) concepts, organizing them into categories (variables), and dimensionalizing the categories.
4. Limited member checking to verify credibility of the emerging categories and dimensions and to obtain additional data.
5. Category development to the extent possible using Phase 1 data.

Participants

Phase 1 participants were students from a large public university (the university), a small private college (the college) and the engineering department of a large polytechnic institute

(the institute) all in the capital district region of New York State. Student participation was voluntary and was solicited in some instances through brief class presentations by the principal investigator. When instructors were unwilling to provide class time for a brief presentation, written material requesting student participation was distributed by the instructor.

Student participation was solicited during the 1993-94 academic year. Because of minimal response in the fall semester, an incentive was used in the spring semester. Each participant's name was entered in a drawing for three monetary prizes.

The initial interview group included 35 students (20 graduate and 15 undergraduate). Most of the graduate students were in some type of education program, and the undergraduates almost evenly split between engineering and psychology. Fifteen (43%) of the participants had completed at least one introductory statistics course before the one which was the focus of the interview. Only six (17%) of the students had fewer than three years of high school mathematics, and two of these had none. However, 22 (63%) had a full four years. In addition, 27(77%) of the students had at least one semester of college mathematics and 52% of these had more than two. All of the engineering students and some of the others had completed at least two semesters of calculus. A complete listing of majors and mathematics background is presented in Appendix A.

While efforts were made to solicit participation by students who found learning statistics easy as well as those for whom it was difficult, most of the participants were students whose experience

was more negative than positive. There is no evidence to suggest, however, that the difficulty was based on lack of effort. On the contrary, many of the students interviewed reported spending considerably more time and effort on statistics than on other courses. The data collected are primarily from otherwise successful students who take their work seriously, but for whom learning statistics was extremely difficult in spite of average to exceptional effort.

Member checking was done with an intact class of 22 undergraduates at the college. A wide range of majors was represented in this group due in part at least to the fact that statistics is one of the courses students may use to satisfy the mathematics requirement the college imposes on all undergraduates. In contrast to the initial interview group, only 27% had previously taken a statistics course. A third of the group had fewer than two years of high school mathematics with two having none, but only 39% had a full four years. The incidence of students with at least one semester of college mathematics at 73% is close to that in the initial interview group, but only 25% of these had more than two compared to 52% on the initial interview group.

Data Collection

All initial interviews were conducted outside of class time in groups of one to four students. The interviews were completely open ended in that the students were encouraged to discuss all aspects of their learning experience whether these helped or hindered

learning. All of the initial interviews were conducted by the principal investigator who was prepared with a list of topics used to stimulate student recollection of learning experiences. These topics were developed from the literature review and personal experience.

To allow the investigator to function as a discussion facilitator, all interviews were recorded. Subsequently, notes were made from review of the tapes. Preliminary category development was done from these data and a set of questions prepared for use in the member checking interviews.

These member checking interviews were conducted during a regularly scheduled class meeting. Because of the size of the class, two groups were formed and the interviews conducted by the principal investigator and another interviewer. While the questions were used, students were encouraged to provide additional data, and the interviewers explored responses as needed. Again, interviews were recorded and notes made from review of the tapes.

Course Format

Except for one student who had taken her introductory course in another state, the students experienced a traditional algorithmic approach to instruction through lecture and practice problems. This is the approach that Zerbolio (1989) aptly labels the "plug and chug" method, and that Pedhauzer (1982), describes as focusing only on the analytic components of statistics with the risk of losing sight of the role of analysis in scientific inquiry.

None of the students had experienced Computer Assisted Instruction (CAI) although a very small number had used computers to do calculations. Only the institute students had used computer analysis, and this was limited to assigned group projects completed outside of class time.

These institute projects were also the only instances of instructor organized collaborative learning for the initial interview group. The member checking group, on the other hand, experienced instructor directed collaborative learning as the standard class format. Few of the students in either group used student organized collaboration as a study technique.

PHASE ONE RESULTS

Phase 1 results are presented below by describing the categories to the extent that it has been possible to develop them from the existing. It is understood that no category is considered fully developed at this point in the study. For all categories, selective coding including focused literature review reviews for additional secondary and verifying data will be undertaken in Phase 2. Also, since category integration is also a Phase 2 activity dependent on the results of selective coding, the Phase 1 results are given as discrete categories with some delineation of sub-categories.

Prior Affect

Range and Sources

Before taking the introductory statistics course, students have attitudes and beliefs ranging from confidence to extreme fear. The affective state is related to the student's mathematics background, but primarily to the student's earlier experiences with mathematics courses rather than the number of courses taken. It is also influenced by negative input from peers, and the student's perception of the nature of the course.

Students who were confident about their ability to handle the course had had positive experiences with math courses. Positive experiences, however, involve more than earning good grades. They include handling the material with ease and enjoying the experience. Confident students spoke in terms of being good at math, having math ability, and loving math. They were also those who chose scientific or technical careers (e.g. engineering, nursing, economics) or those whose parents were engaged in such work.

Not all students who had earned good grades were confident, however. Those for whom math achievement was a difficult, unsatisfying experience in spite of good grades lacked confidence and were fearful about taking statistics. These students were aware that their grades reflected neither ability nor learning. One student reported that she once received an "A" in a college math course based on a final grade of 59, but didn't learn anything. Another considered her experience of being given passing grades in

high school algebra without having achieved learning extremely detrimental. A third acknowledged that his grade in college algebra was based largely on credit for assignments that could not have been done without his wife's direct assistance.

Successful but unconfident students included achievement orientated individuals for whom getting less than an "A" in any course simply is not acceptable. These students will do whatever it takes to honestly earn the desired grade regardless of whether real learning occurs. The learning experience, however, overrides the grade earned and precludes any sense of confidence.

Negative feelings, which ranged from mild concern to terror, reflected limited math exposure, bad learning experiences, a long absence from math involvement, negative input from peers, or a combination of these. The lapse of time since taking a math course was of particular concern to adult students returning after absences as great as as 30 years to pursue a master's degree (usually in education). This concern was compounded if the student's earlier experience had not been good.

Students are influenced by the negative reputation that statistics enjoys. The impact is strong on students with low self-efficacy which is readily diminished by peer reports about how difficult statistics is. Some confident students are able to ignore negative input, but others experience self-doubt when such reports are rendered by peers considered to be academic equals.

Much of the recent APA literature deals with statistics anxiety and thus provides some data on negative affect. This

literature examines the nature and structure of statistics anxiety as well as its effects. Some studies also consider interventions to minimize its impact.

A number of researchers (e.g. Adams & Holcomb, 1986; Benson, 1989; Hunsley, 1987; Zeidner, 1991) have examined statistics anxiety with two very consistent findings about it's nature. First, statistics anxiety has been found to have a structure related to but substantially different from either general anxiety or general test anxiety. The difference lies in the fact that statistics anxiety has a two factor structure including reaction to content as well as performance evaluation. In addition, it has been found that some persons who experience no anxiety in other courses will do so with respect to any course such as statistics which has a mathematical content.

The second persistent finding is a skill deficit model of statistics anxiety paralleling the deficit model of mathematics anxiety Hembree (1988) proposed from a review of literature. According to Hembree's model, the math anxious person is female, has low quantitative ability, fears negative evaluation, dislikes tests and has low self esteem. Similarly, the person with statistics anxiety has been found to fear evaluation and tests, and to have poor quantitative skills with low math self-concept. The most significant correlate with the last two characteristics has been found to be the number of mathematics courses taken.

In contrast to Hembree's model, however, the person with statistics anxiety was not found to be necessarily female. Since

lack of preparation has been found to have the greatest influence on statistics anxiety, it is proposed that gender differences may actually reflect differential course taking between males and females. As Benson (1989) remarks, "thus, gender may have served as a proxy variable in previous math anxiety studies for a deficiency in the number of math courses taken by females" (p. 248).

Data on the the absence of gender difference, per se, are consistent with the primary data. There is lack of consistency, however, on the matter of fear of evaluation and tests, i.e., general test anxiety. None of the students identified general test anxiety as part of their initial affective state although many discussed very specific test anxiety within their statistics course. It is not clear whether the lack of student data on general test anxiety is due to its absence or the fact that its possible existence was not explored during the interviews. This possibility will be explored in Phase 2 of the study.

The literature data indicating that poor quantitative skills and low math self-esteem underlie fear of statistics is consistent with the primary data. The critical issue here is probably best defined as lack of math self-efficacy reflected in doubt about one's ability to successfully handle the course material. The primary data do not disclose any gender differences in this regard, but indicate, as do the literature data, a relationship between lack of self efficacy and the number of math courses taken.

While the question of which of these is cause and which effect is not explored in the literature, the primary data suggest a

relationship that is recursive. Bad experiences with math courses generate poor math self-concept which leads to avoiding math courses which results in poor skill development which reduces the likelihood that any experience with math will be good. Since it is impossible to cancel prior bad experiences which may have contributed to lack of self-efficacy for the college student facing statistics, the more critical issue is how to overcome negative impact.

Persistence

Data from student interviews indicate that the prior affect may persist or may change once the course commences, and that changes may occur in either direction. Anxiety may be alleviated or confidence may be undermined. While anxiety reduction is related to both student and instructor action, loss of confidence is related primarily to instructor attitude and behavior.

Before the course began some students took positive action to deal with their fears and minimize their impact. All of the students who took action were in graduate programs and were older (sometimes considerably) and more experienced than the typical graduate student. While these students did not have greater awareness of their fears and the reasons for them, they were either more cognizant of steps that could be taken or more willing to take those steps.

Some of these students undertook a review of algebra either independently or with assistance from friends. Others identified

individuals who could provide assistance if needed. For example, one secondary French teacher pursuing a master's degree in education spoke of lining up her fellow teachers as potential resources. While using them never became necessary, just knowing she could made her feel more confident. In other words, her sense of self-efficacy was increased by knowing she had a means of dealing with difficulties that might arise.

Both graduate and undergraduate students identified other factors that helped to neutralize their fears once classes began. These include instructor attitude and approach. Having instructors openly acknowledge the existence and validity of student anxieties is important. More important, however, is assurance that the course approach will deemphasize math and follow through on that assurance. Knowing that the course will not have high math demands increases the student's expectation of being able to cope.

Even with a strongly mathematical approach, student's fears are alleviated when they have "an excellent instructor". Students feel more in control when the instructor presents material clearly, at the student's level, and at a reasonable pace. Instructor responsiveness to student needs both during and after class is also important. Again, this is matter of increasing self-efficacy by giving students the means to deal with whatever challenges the course presents.

Students also find that negative affect is diminished, neutralized or even transformed with actual success in learning the material. One student found success so motivating that her initial

concerns were replaced by enthusiasm and a desire to pursue a career in statistics. Instructor enthusiasm, attitude and teaching style were clearly instrumental in producing the success behind this transformation. The further experience of this student, however, shows that positive affect can be destroyed.

After a second course from this same instructor, the student transferred to the university from a community college and was required to take the introductory statistics course in her department on the grounds that the community college courses were not equivalent. She found that course content was not very different, but that instructor attitude and behavior were dramatically so. The impact of this change was difficulty in meeting the course requirements, minimal success with great effort, and complete loss of the earlier enthusiasm for statistics.

Other students experiencing loss of their initial confidence were some those with the strongest math backgrounds. These students had four years of high school math and as much as eight semesters of college math including two or more semesters of calculus. They, like almost all students providing information, perceived statistics as a math course. This perception contributed to their sense of self-efficacy which was undermined when they realized that statistics is qualitatively different form the traditional mathematics at which they excelled. In this regard, it is notable that only these students having a high level of math skill and experience recognized this difference. This was especially true of the engineering students.

An MBA student with an undergraduate engineering degree provided and insightful description of the difference. Engineering, he maintained, is a hard science and is always precise. One plus one is always two. Statistics, however, is a soft science where one plus one is someplace between 1.8 and 2. 2. Statistics always deals with error and tries to eliminate error, but engineering is always precise.

He found the imprecision of statistics troublesome at first because he tried to apply the engineering approach and was disturbed by the conflict. This was not resolved until he understood and accepted the difference between the disciplines. Understanding the difference, he believes, is critical.

On the question of affect change, none of the literature reviewed dealt with the issue of undermined confidence. There was some focus on interventions to alleviate statistics anxiety. These studies, frequently conducted by non-teaching college personnel, also considered whether anxiety reduction affects performance (i.e. grades).

When anxiety reduction techniques were not tied to the learning process, they had an effect on the affective state, but not performance. Sime, Ansorage, Olsen & Parker (1987), for example, studied the effect of direct intervention by trained counselors in classroom settings. Using instruction in the use of relaxation techniques, they produced significant reduction in self-report of anxiety and in physiological indicators of stress, but found that this had no effect on performance.

In contrast, Ben-Jacob (1986) used a workshop approach with math anxious subjects that included discussion of prior math learning experiences, as well as instruction designed to identify and address each student's particular learning problem. She found that participation in the workshop improved both attitude and performance. She concludes that learning environment is critical to promoting competency and confidence and that the best approach for a workshop on math anxiety is to ensure that the participants learn mathematics. These findings validate the primary data.

Impact

Very few students provided data on how their anxiety impacted learning if it did. One graduate student indicated he was constantly aware of his state of anxiety, but was able to control it's effect by reminding himself that he possessed the necessary skills and could learn if diligent. He reported that he was doing well in the course and therefore his anxiety was under control.

The remaining data was focused on how anxiety affected test performance. Students identify anxiety as the source of careless errors which result in test scores not being accurate reflections of their knowledge. If the student has no opportunity to otherwise document learning, the ensuing frustration may undermine future effort.

Secondary data from the literature suggests the manner in which student fears affect the learning process. Huntsley (1987) found that anxious learners frequently fail to attend to cues that

would aid learning since they tend to be more preoccupied with self-relevant variables than task-relevant variables, and engage in negative internal dialogue.

Adams & Holcomb (1986) describe the negative effects of statistics anxiety in terms lack of efficiency (i.e., using energy time and skills in an effective manner). Their findings indicate that efficiency is most affected by specific anxiety and attitude toward statistics. They stress that focusing on content alone while neglecting anxiety and attitude can have detrimental effects.

It is important to note, however, that none of the research reviewed confirmed statistics anxiety as a significant predictor of performance. Rather, GPA was consistently found to be the best predictor of achievement as defined by the grade earned.

Students participating in the initial data collection interviews provided considerable information about their fears and the reasons underlying them. They did not focus, however, on how these fears may have interfered with learning. Neither did they discuss them when responding to open ended questions on what made learning difficult. Given this apparent discrepancy between the primary data and that in the literature, this is an area that will be explored in the Phase 2 of the project.

Learning Goals

Students take Statistics to meet a program requirement, but have varying degrees of understanding of the how the course fits into that program or how it might play a role in their future

professional lives. In behavioral sciences programs, such understanding is virtually non-existent among undergraduates. This is also true of graduate students expecting to terminate their academic work with the Master's degree.

Some graduate education students actually reject the idea that they will use statistics in their professional work. These are classroom teachers whose concern is the individual not the group. This attitude was well expressed by a teacher of learning disabled children.

Being skeptical about reported findings, this student does not read to discover what works for most people. Regardless of what the statistics say, she looks for something that might work for an individual child. She looks for techniques not what the statistics say about them, and makes her own judgements about usefulness. Her selection of techniques from the literature is based more on personal appeal than on statistical significance. "What works for one kid, might not work for another."

It should be noted that this student had a strong background in mathematics including two semesters of calculus. She handled her statistics course with ease and, in fact, provided considerable assistance to students who were having difficulty. Her skepticism about the usefulness of statistical findings in the classroom were not due to lack of understanding of what statistics is about.

Doctoral students in behavioral sciences have a general understanding that they will use statistics in completing their

programs, but this conception is not well articulated at the point at which they take the introductory course. Even these students do not believe they will use statistics in their professional lives unless they expect to work specifically in a research position.

One notable exception to this was a student who had taken introductory statistics in another state prior to enrolling in a graduate education program at the university. She identified two conditions contributing to her awareness. One was the fact that the statistical concepts were always presented in a real world context using real data sets. The other, and the one which makes this experience unique, is the fact that she was engaged in an actual research project at the same time that she was learning introductory statistics.

Those in technical fields, both engineering undergraduates and MBA graduate students, also had a good understanding of how the skills they are learning will be used in their future careers. Both groups attribute this understanding, at least in part, to the course being taught as data analysis and modeling. The engineering students were also involved in very practical data generating projects although not actual research.

These students recognized, however, that they would be statistics users and as such would not need the same level of understanding as mathematical statisticians or even applied statisticians. As one student expressed it, "The course should be geared to the intended use by the student. I'm not going to be a mathematical statistician. I'll be a statistics user. I'll hire a

statistician for the technical stuff. I need concepts". Although expressed in terms of levels of abstraction rather than learning goals, Godfrey's (1988) argument against mathematicians teaching statistics supports this position.

Students who are taking statistics as a program requirement, but believe they will never use it, have a singleness of purpose. Their goal is somehow to endure and complete the course with a passing grade. If they are generally achievement oriented, they will also strive to attain a good grade. In one student's words, "My goal was to get an "A". I had no sense of how I would use statistics in my career even when the material was related to psychology".

These students are quite candid about the fact that they do not expect to learn anything. As one student expressed it, " Doing what you are required to do is what is important. It doesn't matter whether it makes sense or not. Making sense is a bonus". Students identify what is important by what is on the test, but only until the test has been taken. Study techniques are generally memorization of procedures through repetitious reworking of sample problems. When required by the instructor, formulas and definitions will also be memorized. Once testing is completed, all is gratefully forgotten.

Instructor Characteristics

Attitude

Students classify instructors as "good" or "bad" on the basis of a number of characteristics that are independent of the instructional methods being used. This was true for Phase 1 participants regardless of their gender, age, mathematical background, prior affect, and major. For example, a student with only two years of high school math and an admitted lack of math self-efficacy found learning introductory statistics very easy and intellectually satisfying because of a "good" instructor. On the other hand, some students with four years of high school math and as much as six semesters of undergraduate math (including calculus) had devastating learning experiences because of a " bad" instructor.

One of the critical differentiating instructor characteristics is attitude. Perhaps the simplest way to summarize the data on attitude differences is to consider the descriptors in Table 1 that students use to define the attitudes of "good" and "bad" instructors.

The good, caring, supportive instructors took positive action to alleviate student anxieties; constantly reassured students they could succeed; promised to de-emphasize math and did so; were receptive to questions in class; and tried to understand why students were having difficulties. In addition, they were easily

Table 1

Instructor Attitudes

Good Instructor	Bad Instructor
understanding	aloof, superior
enthusiastic	moody
supportive	nasty
"cool"	negative
flexible	bored
caring	caught up in own research
cheerful	has chip on shoulder
concerned about students	just doing a job
easy to talk to	seemed put out being there

accessed outside of class and willing to spend as much time as needed with the student. A caring attitude and its various manifestations made students feel more capable and confident about being able to deal with difficulties that might arise.

The effect of an instructor's support can go so far as to influence the student to persist in the face of other serious obstacles. One student, for example, had extreme difficulty related to the instructor's foreign language and found the course content almost incomprehensible, but found that the instructor sincerely wanted students to learn. She would spend a great deal of time with the student outside of class. The student asserted that she sometimes sat in class without understanding anything just to give

the instructor respect and would have withdrawn if the instructor had not been so supportive.

As much as a caring instructor can create an atmosphere that assists learning, an uncaring one can undermine confidence and increase learning obstacles. These instructors will implicitly or explicitly indicate that students are not capable of learning statistics. On the first day of class one such instructor advised "Look to your left, then look to your right. One of these two people will be taking this course again". The student reporting this incident found it to be extremely disturbing.

These negative instructors show little interest in trying to understand why students are having difficulty or in attempting to help them overcome learning problems. The implication is that difficulty in following and keeping up with the instructor simply indicates the student should not be in the course. In one instance, the instructor publicly referred to a student as stupid because she was having difficulty working a problem.

Even when not explicitly being called stupid, students respond to these negative attitudes by feeling stupid. They lose confidence, become reluctant to approach the instructor for help, and frequently become demoralized. If the student persists under these circumstances, learning is difficult, success limited and the experience extremely stressful.

Student data provide little information on why instructors have a particular attitude, what influenced its development, or what might be done to make negative instructors more caring.

Several possibilities, however, are not indicated. These include age and gender. Also, both good and bad attitudes are found among graduate student instructors and regular faculty. There is some indication of relationship to orientation of the school. The primary data suggest that negative attitudes more likely to be found among long tenured professors at research facilities.

Instructor attitude has a definite effect on learning. Students consider caring of such importance they will go so far as to maintain that individuals should not be a teachers unless they care about students. Good instructors will create a supportive environment which facilitates learning. An uncaring attitude demonstrated in anything from indifference to outright verbal abuse undermines student confidence and increases learning difficulty.

English as a Second Language

Students find that instructors for whom English is a second language present obstacles to learning in two ways. The more obvious is the problem of understanding words because of the instructor's accent. All students who had ESOL instructors found accent an impediment to being able to comprehend lectures. The degree of impediment is related to strength of accent, the manner of presentation, instructor awareness of and willingness to address the problem.

The second problem presented by ESOL instructors is based in their limited command of the English language and lack of cultural understanding. Students find that ESOL instructors have great

difficult in rephrasing material to make it more understandable even when they are willing to try to do so. In addition, examples are sometimes culturally incorrect and serve to confuse rather than clarify.

ESOL instructors exhibit varying degrees of awareness that their accents and language limitations are a factor affecting student learning. This is directly related to the instructor's overall effort to create a supportive learning environment which in turn affects the students' belief in their ability to change the situation.

One student's experience with an ESOL instructor summarizes the problems very well:

- The instructor was aware of her heavy accent and tried to overcome it, but it still was a major problem.
- In addition to stats being as hard as it was, had to try to grasp her English - not just accent, but syntax and grammar.
- It would take a long time for her to come up with an example because of the difficulty in using language.
- It's not fair in such a difficult class to have a non-English speaking instructor.

Instructional Characteristics

Abstractness

Students consider it extremely important that instructors gear presentations to the student's level of understanding. They find, however, that many instructors speak at "senior level" while students are a "sophomore level". Others speak only at their own level of expertise and in a sense do nothing more than display their knowledge. One of the major difficulties students have in learning statistics is that the course deals with "obscure stuff" with which they have had no prior experience and which they are unable to relate to the real world. This expressed difficulty references two distinct but interrelated issues, namely, prior knowledge and abstractness.

The difficulty in understanding abstract presentations which fail to relate the material to the real world is frequently expressed in terms of whether or not the instructor uses real world analogies. As one student put it, "The best way to understand anything is to relate it to everyday experience. Analogy to the real world is critical, even if the analogy is weak."

A finding of particular interest is the fact that the difficulty of understanding abstract presentations was not related to the student's background in mathematics. This problem was experienced by those with four years of high school math and more as well as those with only one or two. One student went so far as to say that the problem was not that the presentation was too

mathematical, but that it was not. She found that the professor did not teach in numbers but in long sentences presenting definitions and explanations but not mathematical concepts. The student was unable to grasp anything that was being said and felt stupid. While this professor was a very experienced instructor of prominence in her department, the student described her as an "ivory tower intellectual" who spoke only at her level of expertise. She was "so smart she can't relate to people not as smart... a brilliant woman who doesn't belong teaching statistics."

This particular student had four semesters of calculus, and had always earned an "A" in her mathematics courses. With the instructor just described she earned a "D" in statistics, but subsequently repeated the course with a different instructor (a graduate student) and earned an "A". A critical variable in this difference was the fact that the second instructor spoke at the student's level of understanding. The student recalled hearing things the second time and thinking, "Oh, that is what she [the first professor] meant".

While they may not articulate it well, students draw a clear line between the algebraic components of statistics and presentation of information in symbolic form. The first, which includes using formulas to solve problems, plugging in values and solving the resulting equations is what students mean by their use of the term mathematics. They do not include abstract symbolic thinking. This distinction appears to be in pronounced contrast to the use of the term mathematics by statistics teachers and

researchers. While professionals in the field understand and accept that mathematics encompasses much more than computational use of formulas, students do not.

Except for the two students who had not had any high school or college mathematics, the study participants did not experience difficulty with the mathematics as they use that term. They had great difficulty, however, when material was presented in abstract symbolic form. This is exactly what the student just referenced was saying. Other expressions of this are observations that statistics has its own language; that the instructor always used statistics language rather than real world language; or that the presentation was very abstract, but not too mathematical.

Additional evidence of abstractness being a problem is the fact that students report a distinct change in course difficulty at the point of transition from descriptive to inferential statistics. Most students handle descriptive statistics with relative ease although for some even this part of the course is very challenging. To some extent facility with descriptive statistics is related to having taken statistics in high school. But even for some students with this experience, facility did not persist into inferential statistics.

One undergraduate psychology student's experience illustrates this situation very well. She reports that the first part of the course was going over what was done in high school - means, etc. It was more concrete, more related to real things. Then the course got so abstract, she couldn't relate to it anymore. "I would look up at

symbols and numbers and not know where to begin...I can't really relate this stuff to the real world. It's like another world". This experience produced a great deal of frustration.

This student had an excellent relationship with the instructor who provided considerable assistance outside of class and helped the student deal with her frustration. While there was a foreign language factor, the instructor tried to overcome it and present the material so students would understand. Given the time and effort the student was expending and the support received from the instructor, the student concluded that the problem lay in the nature of the material, not in the instructor's handling of it. She did not perceive that there could be a way to present the material in an understandable manner to eliminate frustration.

The literature reviewed contains limited but important data on abstractness as a variable in learning statistics. The work of Ben-Jacob (1986) cited earlier suggested that lack of a well developed "faculty of abstractness" may account for lack of success in learning statistics. This suggestion points to the possibility that lack of cognitive maturity may be more pertinent than mathematical preparation to student difficulty in dealing with an abstract presentation of statistics.

In an excellent review, Garfield and Alghren (1988) cite a number of studies indicating that as many as half of the students in senior high school are unable to think at the level of Piaget's formal operations. That is, "... they do not completely grasp proportionality, hypothetical argument, or the concept of

controlling variables..." (p.50) which are essential elements of statistics as it has been taught.

More recently, Hudak & Anderson (1990) found that success in introductory statistics is related to formal operational ability and that a concrete style of learning is particularly maladaptive in statistics. They found specifically that, "...the ability to act consistently at the formal operations level and a preference for abstract learning were predicted to discriminate successful from unsuccessful students in both statistics and computer science courses." (p. 232).

In addition, Johnson (1989) found success in using concrete demonstration to teach ANOVA concepts and Zerbolio (1989) reported favorable student reaction to a technique using an imaginary bag of marbles to teach both probability and sampling distribution. While these studies, unlike Hudak & Anderson (1990), did not include assessment of formal vs. concrete operational level, they do provide evidence that use of concrete referents facilitates learning for some students.

The primary and secondary data are quite consistent in identifying abstractness of presentation as a variable that affects many learners. They also identify that abstractness is different from mathematical skill. As Zerbolio (1989) puts it,

> To solve statistical problems, one uses more logic than math skills. Unfortunately, too many students believe statistics is mathematics....Too often this means students adopt a <u>plug and chug approach</u> (i.e. fill in the numbers and arrive at a

correct numerical answer)....With the plug and chug approach, students typically fail to grasp the meaning and logic behind statistical procedures and, therefore, rapidly forget what they have been taught. (p.207)

It seems necessary at this point to remind the reader that most of the students in this study took a "plug and chug" approach because that is the way they were being taught and that is what was expected of them. Nevertheless, they were aware of the need to understand the logic of statistics and the difficulty of doing this when the material was presented in a highly abstract manner.

Prior Knowledge

The prior knowledge issue encompasses both lack of domain specific prior knowledge and the absence of instructor activity to access relevant general knowledge. Students recognize that he algebraic skill they have acquired through studying mathematics is not sufficient prior knowledge. They realize there is other critical prior knowledge which they lack. They find, however, that some instructors fail to understand this lack. As one student put it, " The professor started at a point beyond my knowledge level. I felt unprepared in spite of four years of high school math". This student reported no difficulty doing the mathematics once values were plugged into formulas.

Students also recognize that neither ordinary life experiences nor their previous academic work - including mathematics - provided the necessary prior knowledge. Again, students exhibit awareness of

the distinction between statistics and mathematics discussed above. The mathematics is recognized as a prerequisite skill but not the totality of prior knowledge. Therefore, to facilitate the remainder of this discussion, the term "prior knowledge" will be used exclusive of mathematical skill.

One of the engineering students described his usual mode of learning is to make the new things relate to other classes. He looks for common things or something to which he can relate the new material. When this is done, the new material makes sense. In the case of statistics, he was unable to relate the material to any of his other classes, nor was he able to draw on any other experience. Since the professor was not "doing this kind of thing" (i. e. connecting to prior knowledge), the student continued throughout the course to have difficulty gaining understanding even though he was successful with the "plug & chug" activities.

There is a strong sense among students that it is this introductory course which should provide the basic knowledge which is not obtainable elsewhere. As one engineering student expressed it, "There is no way for us students to know what these theories are like. We're just starting. They [the instructors] have been doing it for years. They can say something out of the blue and get meaning".

A graduate education student for whom the mathematics was not a problem, but who acknowledged that she sat in class really lost, speculated that taking an undergraduate course in preparation might have helped. She believed this might have provided familiarity with

the terms the instructor seemed to assume the students understood. This belief was influenced by her perception that those in the class who had an undergraduate course were not experiencing the same difficulty as she.

The experience of another student in the same class validates this belief. Before taking the course in which he was enrolled at the time of participating in the study, this student had taken two undergraduate introductory statistics courses and a research methods course. He categorized his current course as slow paced and somewhat below his ability level, but acknowledged this did not seem to be true of the class as a whole. At least part of the difficulty for these students, he believed, was based on the fact that they were not familiar with the terms used or the ideas being discussed.

The experience of those who had taken statistics in high school is also relevant to this issue. These students found that they understood the early segments of the course, but that presentations became completely incomprehensible when the course focus shifted from descriptive to inferential statistics. While the abstractness issue discussed above is pertinent, it must also be recognized that the high school experience provided at least prior procedural (and perhaps conceptual) knowledge which served as a cognitive framework for the descriptive, but not inferential, portions of the course.

As discussed above, students consider use of analogies and important in making the course material more concrete than

abstract. They also realize that this technique helps to connect the material to their prior knowledge. Since the only prior knowledge for this introductory course is everyday experience, analogy to those experiences facilitates learning. Students found this to be the case not only when concepts were presented with reference to everyday experiences, but also when problems used real world scenarios rather than data from laboratory experiments or totally made up values.

While there is considerable literature dealing with prior knowledge in general or in other disciplines, that addressing the role of prior knowledge in learning or teaching statistics appears limited. A few authors (Allwood, 1990; Evans, 1988; Evans & Evans, 1989) found that existing knowledge schemas could be used as aids in learning statistics when the existing schemas are elicited through metaphors. In addition, there was evidence that learning statistics from metaphors produces new knowledge structures.

Pacing

The problem students experience in trying to cope with highly abstract presentations and/or absence of prior knowledge can be compounded when the lecture is fast paced since either of these conditions creates a need for increased processing time. When no allowance is made for this, the student may become completely lost and discouraged. One student described this situation as being light years behind by the time he transcribed what the professor was saying into something meaningful.

Another student reported that the pace of instruction was so fast she could not consider following the thought process. All she could expect was to "copy every word and hope to understand later". Even with that limited expectation, she couldn't always copy fast enough to get complete notes.

Students believe several factors may influence the pace of instruction. Some instructors seem to gear the pace to the more capable or more experienced members of the class. Students providing these data had a clear perception that class composition was extremely heterogeneous with regard to previous experience in statistics. In fact, students sometimes made reference to the "repeaters" in the class whose repeat status had nothing to do with prior failure. Rather, these repeat students were seen as already knowing everything, able to read the book, and just reviewing the course. No data are available on overall class composition, but the fact that even among the initial interview group 15(43%) of 35 of the students had previously completed at least one introductory statistics course lends support to this perception.

Also, the pace of instruction in some instances appears to be controlled by the instructor's predetermined plan. Some instructors seem to consider it more important to cover planned content than to ensure student learning. One instructor was described as compulsive about completing the syllabus even though she knew she was going too fast and losing some of the students. This was frequently the case among graduate student instructors who appeared to be constrained by department imposed course requirements. However,

some very experienced instructors were found to be unwilling or incapable giving student needs precedence over covering content.

Teaching Concepts

Students speak of not having "the big picture", having no idea what to do with results, or never having a good idea of how things worked. They describe their experience as being worried about tons of formulas without understanding what those formulas are for even when real world examples are used. In some instances, students were able to identify this problem as lack of conceptual knowledge.

One engineering student reported hat he had no idea of what to do with results because he didn't have a firm grasp of concepts and couldn't get away with just using procedures as he did in math. Another indicated that he usually didn't need to have diverse applications in problem sets, but definitely did in statistics because he didn't understand concepts. He was aware that the instructor was not "making things connect", and speculated that having more diverse problem experience might have provided a means of acquiring conceptual knowledge.

While instructors usually identified the referents for the symbols used in formulas, and illustrated how to substitute values, few of them provided instruction about statistical concepts. According to one student, "A lot of professors don't explain what they are saying. They just write formulas without basis". Another commented that she never had a good explanation of

how statistics works and that, "The explanation professors give does not constitute teaching concepts".

The degree to which lack of conceptual instruction presented a problem was related to student goals, expectations, and learning style. As discussed earlier, some students wanted only to survive the course and did not expect to acquire any lasting knowledge. These students did not focus on lack of conceptual instruction as a problem although they did acknowledge this absence when questioned about it.

Those who were focused on the problem expressed a strong belief in the necessity of instruction on concepts before learning formulas. This belief was articulated well by a graduate education student who had some conceptual knowledge by virtue of having taken both statistics and research design previously:

> It seems confusing to other students. Each class should have a introduction as to what tests are used where and what results mean. Some students are just not conceptualizing. It's difficult to retain without a conceptual context to provide relevance.

One study from the statistics literature reviewed provided support for the primary data on the need to teach concepts before procedures. In an experimental study, Hong & O'Neill (1992) found that teaching introductory hypothesis to novices was more effective when concepts were taught separately and in advance of procedures.

Strategies

Another serious problem students have is selecting the correct formula to use in solving a problem when this skill is required. The impact of this problem on testing will be discussed in a later section of the report, but at this point the relationship of the problem to instructional practices needs to be examined.

One of the contributing conditions is that assigned problem sets are usually related to one procedure and selection skill is not required. Thus, students do not get enough practice to develop the skill. They believe instructors should provide more experience in working with mixed problem sets, but this change alone would not entirely resolve the problem.

Students also identify a need for explicit instruction in strategies for mapping formulas to problems. As noted many times, students did not have difficulty doing the calculations required in problem solving. Their difficulty was with problem interpretation and finding cues that would trigger formula selection. They were unable to develop problem interpretation strategies independently, and found that most instructors did not teach any.

Errors

Only a small number of students experienced an instructor who routinely or frequently made errors in presentations. All of these students indicated, however, that this circumstance was a very serious obstacle to learning. To begin with, students who are already finding it difficult to learn are usually unable to

identify the errors or may lack the confidence to challenge the instructor. Unless these are pointed out by someone else and corrected, the student may experience unresolvable confusion.

This problem is exacerbated if the instructor is defensive about having errors pointed out by students. One student who experienced such a situation reported that she needed to learn in advance in order to pick up the instructors errors and accommodate them. Being a graduate student taking the course as a refresher she was able to do this but realized that those taking the course for the first time could not. She indicated that the instructor, who was not experienced, seemed unaware of the numerous errors being made and was not receptive to being corrected by students.

Equally problematic is an instructor who is aware of making errors but callous about the problem this created for students. In one such situation, the instructor, who was experienced, constantly use examples in which "the numbers didn't check". He was aware of this but told students it didn't matter and that they should "just understand". The student reporting this experience indicated that he was never able to understand during class because of the fast pace of the lecture and the constant errors in numbers. He had to learn on his own outside of class, and doing this from notes containing errors was both extremely difficult and time consuming.

Textbook

Student learning is affected by the choice of textbook, the manner in which it is used, and the degree to which the text does or does not map to the instructor's presentation (or the reverse). While recognizing that textbooks are important learning tools, students frequently found it impossible to use the text for that purpose. In many instances, the text was nothing more than a reference for formulas and tables.

The many different textbooks used by the students in this study were characterized as good or bad primarily on the basis of "readability" (i.e. understandability). The qualities entering into that judgement are essentially the same as those entailed in determining whether an instructor's presentation is understandable. Students describe unreadable texts as those which assume too much prior knowledge, present material at too high a level, are too technical, do not relate to real world experiences, present no conceptual material, and fail to explain formulas in context.

One student summed this up by explaining that he usually did not read textbooks, but had to for statistics because he could not understand the instructor's presentation. Reading the text provided very little help, however, because there were too many sigma signs and complex formulas. He never knew where to start to make it simple so he could understand. In addition there was more math than needed, inadequate coverage of concepts and no information on how to connect formulas to problems. He couldn't get it in class;

couldn't read the book; became frustrated and didn't know what to do.

Having an unreadable text was a serious problem since it significantly reduced the student's opportunities to learn. the problem was extreme when both the instructor's presentation and the textbook were incomprehensible. This was frequently the case since instructors tended to choose textbooks that matched their instructional styles.

While such matches were problematic, of even greater concern was lack of mapping between instructor and text especially when the instructor's presentation was poor. One difficulty in this situation was use of different notation by instructor and text. Students were able to accommodate this if the instructor explained the differences, but were totally confused when such explanations were not provided. Other sources of difficulty were unexplained differences in terminology, organization of explanatory material, and sequencing of topics. One student described the process required to match the instructor's presentation to the text as reading in another language and translating.

Information provided by one of the graduate education students was particularly relevant to this issue. This student holds a master's degree in English and is on faculty at a community college where she teaches study skills among other things. She was taking statistics as a requirement in an Education Administration program. She had no difficulty with the mathematics, but found that she could get neither concepts nor context from the instructor's

presentation. Because it was important to her to gain understanding as well as "plug and chug" skills, she routinely studied from three textbooks in addition to the assigned text.

She found that each of these texts presented the material differently from each other and from the instructor. Coordinating was a very time consuming process, but since it was ultimately productive she persisted with it. She reported that she "just kept reading and rereading "until something clicked" spending as much as six hours at this task for a single concept. The text she found most helpful was an undergraduate text which tied the formulas to meaningful situations and real world problem solving.

One very puzzling finding is that another student in the same class described the assigned text as excellent. Among the favorable features she cited were use of material soon after presentation, frequent learning checks, and review of material in subsequent chapters. This student is a secondary French teacher also in the Education Administration Program. Even though these two students were of approximately the same age with similar academic backgrounds and experiences, their reaction to the textbook and to the instructional style were extremely different. The interview data did indicate goal differences for these two students. The first constantly expressed concern that the course format was completely "plug and chug", but the second seemed satisfied with this. It appears that there are significant individual differences contributing to this situation, but they are not identifiable from the available data.

Testing

Mapping to Instruction

Students considered it extremely unfair when test content and/or format do not correspond to those used in lectures and/or assignments. Students are demoralized when they are asked to execute skills they have not had an opportunity to practice, to use strategies that have not been taught, or to display conceptual understanding when this has not been required during class.

Difficulties are frequently related to the fact that classes and assignments have focused exclusively on isolated use of techniques, but tests include definitions or word problems. This extends to phrasing problems in a way the student has not seen. For example, one student reported being thrown by a direction to "transform" when all prior problems had been in the format, "Given a and b, find c".

Students are also very concernd that they receive no instruction in analyzing a problem to determine the appropriate procedure to use, but are expected to do this on a test. Class experience typically involves using one procedure at a time learning how to plug in values and do the calculation. Since no experience in "thinking out problems" is provided, students find they lack this skill when it is needed.

Students frequently remark that they thought they understood in class, but couldn't perform on the test. These remarks appear to indicate that they knew how to use techniques separately, but

lacked ability to use them in an integrated fashion. As one student expressed it, "I understood little pieces. The problem was putting them all together and using them on test questions."

This piecemeal understanding was very pronounced among the institute engineering students whose testing experience differed in one critical respect from that of the other students. In line with the Total Quality Mamagement (TQM) principle of providing immediate feedback, the institute faculty employed the practice of a daily quiz. At the end of each lecture, the student responded to one open book question based solely on that lecture's material. Otherwise there was a mid-term exam and a final.

The daily quiz was intended to be an indicator of how well the student was doing, but the information was misleading. Students thought they were doing well because they were successful on the daily quizzes; that they had a good grasp because they understood all the pieces. They found, however, that when they tried to put all the pieces together they fell short. The fact that they did not discover this until mid-term made the situation difficult to address.

Some of the institute students also experienced difficulties because tests were constructed by the department, not the individual instructor. While most of the instructors followed the data analysis and modeling approach reflected in the tests, at least one instructor took a more traditional mathematical aprroach. This created a serious lack of mapping from instruction to test.

Students involved in this situation commented that it would have been better if the tests were matched to the style of the teacher.

Another extremely difficult aspect of test taking is the use of multiple choice and modified multipel choice questions. This difficulty is related not only to lack of experience with the format, but also to instructional focus on procedures rather than concepts. Students do not develop conceptual knowledge from learning rpocedures, nor do they necessarily do so from independently using other resources such as the textbook. One student described her situation as the test problems being professor style, and the multiple choice questions being drawn from the textbook which was beyond her comprehension.

The lack of mapping from lectures and assignments to test content and format is equally problematic if the procedures/ concepts relationship is reversed. A student who experienced instruction in terms of definitions and broad concepts with assignment being limited to reading was as disturbed in facing a test on problem solving as were those instructed in procedures and tested on concepts.

Students believe that some of the problems related to the lack of mapping from instruction to tests could be addressed if they were provided with sample tests to get some sense of format and style of questions. They consider it important for the instructor to provide accurate information on test structure as well as content.

Memorizing

The requiremnet to memorize definitions for tests was not was not reported by many students, but for this limited group it was universally a problem. Students are very cognizant of the fact that it is possible to memorize without underatanding and that the memorization process does not necessarily facilitate understanding. They also believe that it takes valuable time from other activities that might promote understanding.

One particular group of graduate students was required to produce as many as 50 rote definitions on a test and were penalized for making even minor errors in wording. Because they were achievement oriented, they did whatever it took to to meet the demand. In some instances this involved developing elaborate memorization schemes. They were upset by needing to do this, however, and considered the verbatim memorization requirement an exremely unfair and invalid assessment of their learning.

Of those students required to memorize formulas for tests some found the process helped them learn, but most did not. Students believe there is no real point to memorizing formulas. They should be provided or students should be allowed to bring them to the test. One student went so far to say that the professor providing formulas on the test had more to do with his "A" standing than anything else.

With professor provided formulas, however, there are concerns that the manner of presentation be consistent with what the student

has experienced during instruction. For example, one instructor who had always written formulas on the blackboard, for the test presented them in typewritten format prepared on a standatd typewritter. The student found it difficult to recognize the formula in this form. She also found that overcoming this difficulty consumed test time and thereby raised her stress level.

Frequency

Students strongly favor frequent tests. Four to six per semester is considered optimal, and having only a mid-term and final is unacceptable. If students must wait till mid-term to learn that their self-assessment of understanding is inaccurate, the task of catching up is overwhelming. Also, there is more pressure with only two tests. As one student put it, "If I have a bad test day, I could lose 30-40% of my grade". Students consider it important to have enough tests to allow the student to average out good and poor performance.

Another reason for frequent test is to provide experience that cannot be gained in any other way. As one student put it, "A person not accustomed to working with the material will be inclined to make careless errors. Experience with tests helps reduce those errors". In this regard, students find that experience with assignments or problems worked in class is not sufficient because of the dicrepancies between the types of questions on tests and those used in class or assignments.

Test Conditions

Students are concerned about having sufficient time to complete tests. They also believe instructors need to give more attention to basing time allotments on the student's problem solving skills rather than their own.

Equally important is scheduling the test to reduce test related stress. In this regard, students find the practice of giving a test in the second half of a class after a lecture completely unacceptable. This practice makes the test harder than it needs to be, and increases stress which affects test performance.

Test Review

Students believe that tests should be used as a means to determine the level of their learning and degree to which they have mastered what has been taught. They also have a distinct sense that tests and grading should be criterion referenced. In addition, they understand the value of tests as a learning tools and expect that tests should be formative.

Instructor practices in this regard vary greatly. When detailed review occurs, students cite it as facilitating learning. When it does not, students students believe they are deprived of valuable information that could influence their future performance. This situation is especially disconcerting if the student is not allowed to keep the test, and is thereby denied the opportunity to use it as as source of learning.

impact of Problems

When students have invested considerable time and effort in learning, but perform poorly on test for any (or all) of the reasons discussed, they are demoralized and frequently experience a change in attitude. Motivation is diminished and the amount of time and effort reduced. From the experience, the student gets the message that is that there is no way to succeed and, concludes there is no point in continuing to try.

Severity of the attitude change depends on the degree of disprity between effort and success. It is also influenced by the student's perception of intent to give a test that is beyond the student's ability level. This was the perception of the institute students who believe that it is the policy of the school (for whatever reason) to give tests that will discourage the student.

These students offered a number of relevant comments:

- Being shown you're an idiot in the statistics sense is disturbing.
- The test made me think that maybe I can't learn stat concepts; maybe I should just memorize what I need to pass.
- Mid-term sent a message to memorize and not worry about learning.
- I've taught and made up better tests; anybody can write a test no one can pass.
- With the average as low as it was, that says something about the test not about the students taking the test.

- As prepared as I was for the test, it was the kind of test you had to be a stat genius to get a really good score.
- TA's confirmed they found the test very difficult. A lot of them took as much time to do the test as we did. As grad students they should be able to do it better and faster.
- Profs made up the test from their own perspective. Maybe they should have changed roles and looked at it from the students' oerspective. and said, "this is an introductory course, they haven't read 50 million books and don't have the background".
- Only course didn't get an "A" without a curve.

In response to student's being discouraged by the mid-term, instructors offered bonus questions on the final. Many students, however did not have time to do the bonus questions. Also because they were led to believe the bonus question was more difficult than the main test content, students delayed considering it only to discover that they could have handled to more easily the main questions. Without the caution, time might have been allocated differently.

SUMMARY AND DISCUSSION

While the students' theory of learning introductory statistics is not fully developed at this point, many critical variables have

been identified, and these strongly suggest teaching ability as an integrating category. Many students explicitly identified teaching ability or lack thereof as the single most important contributor to their success or failure. Others clearly implied this in the data provided.

Teaching ability is a complex variable having many interrelated components. A compilation of features drawn from the student data delineates these components quite well. According to students, the able teacher:

- Is interested in teaching; not just a job;
- Cares about students; interested in them;
- Is aware of student anxieties and difficulties;
- Creates a supportive environment;
- Is aware of learning differences among students and adapts to them;
- Provides motivation;
- Talks at the student's level; uses real world language and examples; applies to everyday life;
- Assumes no prior knowledge;
- Deemphasizes mathematics.
- Uses data sets drawn from real world situations; uses class generated data sets;
- Discusses concepts extensively; initially presents concepts in non-mathematical terms; relates concepts to data sets;

- Gears pace to class; adjusts syllabus to what is happening in class;
- Is receptive to questions; uses different explanations and examples in response to questions.
- Interacts with the class; responds to confused expressions by re-explaining; stops and solicits questions;
- Works problems with class; gives adequate practice with a good variety of problems;
- Gives strategy instruction during class;
- Reviews assignments and tests in class;
- Accessible outside of class hours.

In considering this emphasis on teaching ability, it is extremely important to recognize that the participants in this study were conscientious students accustomed to being generally successful in their courses without expenditure of great effort and without excessive concern about the caliber of instructors. In other courses these students are able to learn independently from alternate sources when instructors are ineffective. In statistics, this was usually not the case even for students with strong backgrounds in mathematics.

Of those participants who found learning statistics easy, most fit this description but had a very good teacher. Those whose ease of learning was not related to teaching ability attributed it to their own ability but were unable to elaborate on this variable. Clearly, there are students whose ability makes them impervious to

the learning environment and who do not need to be taught. Just as clearly, there are students who have sufficient ability to learn statistics, but only if they are taught effectively.

Through ethnographic studies such as the one in progress, students will tell us what effective teaching is. The question is whether educators and researchers will listen and act upon what they hear.

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COLLEGE STUDENT'S

THEORY OF LEARNING STATISTICS

APPENDIX A

PARTICIPANT PROFILES

INITIAL INTERVIEW GROUP

Current Major	Ugrad Major	Prior Stats	Yrs HS Math	Semesters Col Math
Institute Undergraduates				
1. Engineering		0	4	6
2. Engineering		1	4	4
3. Engineering		0	4	4
4. Engineering		0	4	5
5. Engineering		0	4	5
6. Engineering		1	4	6
7. Engineering		0	4	3
8. Engineering		1	4	5
College Graduate Students				
1. School Couns.	Psychology	1	1	0
2. Special Ed.	El. Ed/Math	0	4	7
3. Bus. Admin.	Pol. Science	1	4	1
4. Bus. Admin.	unk.	1	4	8
5. Col. Stu. Pers.	unk	0	3	0
6. Col. Stu. Pers.	unk.	0	2	0
University Graduate Students				
1. Ed. Psych.	English	0	0	0
2. Ed. Admin.	English	0	4	2
3. Ed. Admin	Nursing	0	3	0
4. Psychology	Psychology	2	1	2
5. Ed. Psych.	Psychology	1	4	2
6. Ed. Psych.	English	1	3	0
7. Ed. Admin.	French	0	3	0
8. Couns. Psy.	El. Ed.	1	3	6
9. School Psych.	Psychology	1	4	2
10. Ed. Admin.	English	0	4	1
11. Ed. Psych.	Special Ed.	0	1	1
12. Ed. Psych.	Psychology	0	1	1
13. Couns. Psych.	Psychology	1	4	2
14. Poly. Sci.	Poly. Sci.	1	4	3
University Undergraduates				
1. Psychology		1	3	1
2. Sociology		0	4	1
3. Psychology		0	4	0
4. Psychology		W*	4	4
5. Psychology		3	3	3
6. Psychology		0	4	0
7. Psychology		W*	4	2

* W indicates student withdrew before completing course.

MEMBERCHECKING GROUP

	Current Major	Prior Stats	Yrs HS Math	Semesters Col Math
College Undergraduates				
1.	Accounting	0	4	1
2.	Computer Science	0	1	2
3.	Computer Science	0	3	1
4.	Bus Financing	0	0	2
5.	Undecided	0	4	0
6.	Sociology	0	3	1
7.	El. Education	0	0	0
8.	Undecided	0	4	0
9.	Psychology	1	4	2
10.	Accounting	0	unk.	3
11.	Bus. Admin.	0	unk.	unk.
12.	Mathematics	0	2	8
13.	Psychology	0	3	0
14.	Bus. Admin	1	2	1
15.	Bus. Admin.	0	4	3
16.	English/Sociology	1	4	0
17.	Bus. Admin.	1	3	1
18.	Psychology	0	3	1
19.	Bus. Admin.	0	2	2
20.	Music Education	0	unk.	2
21.	History	1	4	1
22.	Undecided	1	unk.	3